RESEARCHPAPER

Macroinvertebrates as bioindicators of Water Quality of Effluent-receiving Ossah River, Umuahia, Southeast Nigeria.

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A B S T R A C T:
Bioindicators are biological organisms that can be used to monitor the quality of the environment. Macroinvertebrates are known to be extremely sensitive to organic pollutants coupled with their wide distribution, ease and minimal cost of sampling which makes them perfect bioindicators. Macroinvertebrate fauna of an effluent-receiving River Southeast Nigeria was studied in 3 stations between January and June 2018; to assess their community structure in relation to effluent discharge and other anthropogenic activities. The modified kick sampling technique and sweeping of aquatic macrophytes with hand net were used in the sampling of the macroinvertebrates. Five taxonomic groups and twenty (20) taxa were recorded; contributing 119 macroinvertebrate individuals. The composition of the taxa showed that non-biting midge, *Chironomus* sphad the highest number (39.5%). In terms of spatial distribution, the highest number of individuals (57) was recorded in station 2 while stations 3 and 2 had 37 and 25 individuals respectively. The macroinvertebrates fauna was dominated by tolerant species (75%). The diversity indices as reflected in Shannon-Wiener index (H) (1.717 - 1.923), Magalef Species Richness (2.769 - 2.968) and Evenness index (0.4285 - 0.6843) were low indicating lower number of species and environmental degradation due to anthropogenic impacts. The physicochemical parameters and macroinvertebrate assemblages showed that the river was adversely impacted by effluent discharge and other anthropogenic activities. The physicochemical parameters showed that station 1 was polluted by cumulative impacts while macroinvertebrate assemblages showed that station 2 was polluted by effluent discharge.

INTRODUCTION:

Freshwater ecosystems are progressively more subjected to anthropogenic stressors in the forms of chemical and organic discharges, habitat alterations of the water channels and adjoining areas as well as land use changes and climate change (Goldschmidt, 2016). Surface water qualities of aquatic systems in watersheds have been significantly degraded due to anthropogenic activities (Anyanwu, 2012; Amah-Jerry *et al*., 2017; Mohammed and Bamarni, 2019).

The use of macroinvertebrates in biological monitoring has shown consistency and reliability in relation to the use of other organisms because of their sensitivity to organic pollutants, wide distribution as well as the ease and minimal cost of sampling (Kalyoncu and Gulboy, 2009; Setiawan, 2009). A number of factors such as water quality, substrate type, sediment and particle size, flow regime, nutrient availability, dissolved oxygen level as well as the prevailing conditions in the watershed determine the community structure of benthic macroinvertebrates (Ward *et al*., 1995; Buss *et al*., 2004).

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Several studies in lotic environments have used benthic macroinvertebrates for biomonitoring and assessment of aquatic ecosystem health because of their potentials for long term anthropogenic impact monitoring programmes (Simboura *et al*., 1995; Emere and Nasiru, 2007; Spaak and Bauchrowitz, 2010; Arimoro *et al*., 2015).The organic pollution of water resulting from domestic and industrial discharges is a common source of perturbation on urban watercourses (Souto *et al*., 2011). These discharges affect the physical and chemical characteristics of running water systems leading to changes in the benthic macroinvertebrates community structure (Hynes, 1970; Ward *et al*., 1995).

Ossah River is an urban river that receives industrial effluent from a vegetable oil processing factory and also subjected to other anthropogenic impacts (sand mining, bathing, swimming, washing of clothes and extraction of water for drinking).The objective of this study was therefore to evaluate macroinvertebrate community structure in relation to anthropogenic stressors and water quality.

2. MATERIALS AND METHODS

2.1. Study area and sampling stations

The study area was Ossah Ibeku Community, Umuahia North Local Government Area, Abia State, Southeast Nigeria while the studied section of Ossah River lie within Latitude $05^o29^'20.00"$ - $05^o31^'40.00"N$ and Longitude $07^o27'50.40"$ - $07^o28'548.00"E$ (Figure 1). The river was divided into three stations for the purpose of this study. Station 1 is the upstream and control station, located in Ahi Amanso, Ossah community. There are a lot of construction activities going on the area as a result stormwater from the sites discharge into the river. The station is relatively deep (69.3 cm) and the substrate is sandy. Direct activities observed in the station include sand mining, bathing, swimming, washing of clothes and extraction of water for drinking. Station 2 is located at Eziama Ossah, 510m downstream of station 1 and 410m downstream of the effluent discharge point. It is shallow (62.7 cm) and sandy with minimal activities like washing and bathing. Station 3 is located at Umuchime Ossah, 610m downstream of station 2. The station is by a bridge along a road under construction. The station was deep (79.5 cm) with a sandy substrate. Stormwater from the village discharge into this station during the rains; depositing sand on the edge of the river. Human activities observed include fishing, bathing, swimming, washing of motorcycles, tricycle (keke) and clothes as well as extraction of water for drinking.
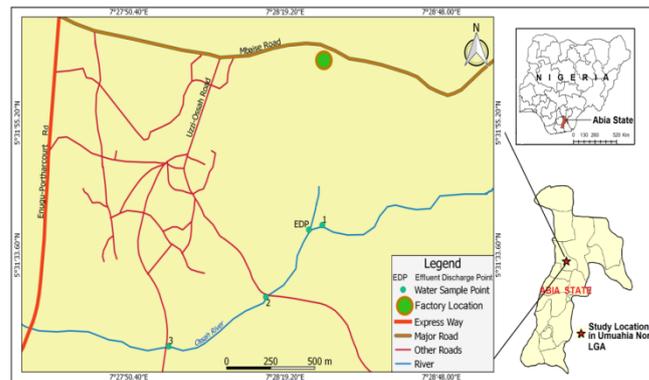

Figure 1: Map of Umuahia, Abia State, Nigeria showing the sampling Stations of Ossah River.

2.2   Samples collection and analyses

The river was sampled monthly for physicochemical parameters and macroinvertebrate fauna between January and June 2018.

2.2.1   Water Samples

The water samples were collected in sterilized 1litre plastic bottles and transported in ice chests to the laboratory for analysis. Parameters like temperature, pH (Hydrogen ion concentration), Electrical Conductivity and total dissolved solids were determined insitu while Dissolved Oxygen, Biochemical Oxygen Demand, Nitrate and Phosphate were determined in the laboratory with the appropriate methods by American Public Health Association (APHA) (1998).

The Descriptive Statistic Package of Microsoft Excel was used to summarise the data while one-way Analysis of Variance (ANOVA) was used to test for significant variations among the stations and the post-hoc analysis to identify the sources of significant variations used Tukey's pairwise comparisons (Hammer *et al*., 2001).

2.2.2   Macroinvertebrate Samples

Macroinvertebrate samples were collected from the sediments using the modified kick

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sampling technique described by Victor and Ogbeibu (1985). The sediment upstream was disturbed by kicking with foot for about 5 minutes and the macroinvertebrates dislodged were washed into the net placed downstream of the disturbed point. Aquatic macrophytes along the banks of the river were also swept with the hand net against the water current and the macroinvertebrates dislodged were washed into the net (500µ).

All the samples were preserved with 10% formaldehyde in a plastic container and taken to the laboratory for proper identification. The isolated macroinvertebrates were identified to the lowest possible taxonomic level with the aids of the following taxonomic keys: Pennak (1978), Brown (1994) and Merritt and Cummins (1996). The numbers were counted. Margalef (D) and Shannon (H) indices were used to determine species richness and diversity respectively while Evenness index (E) was used to assess the even distribution of the recorded macroinvertebrates.

3. RESULTS
3.1 Water Quality

The summary of physicochemical parameters recorded in Ossah River is presented in Table. 1. The water temperature levels were between 21.0 and 28.0^{o}C. Temperature values were within acceptable limits. All the pH values were acidic ranging from 4.6 to 6.3 and outside acceptable limits for aquatic life (6.5-8.5). Station 1 recorded the lowest mean value (5.4). The electrical conductivity (EC) and Total Dissolved Solids (TDS) exhibited similar trend and the mean values decreased from station 1 to 3. EC ranged from 52.9 to 110.5µS/cm while TDS ranged from 25.7 to 55.3 mg/l. There was significant different ($P < 0.05$) in the three stations. The values of dissolved oxygen (DO) was between 3.2 and 6.4 mg/l; all the values were lower than the acceptable limit (>6mg/l) except one. The biochemical oxygen demand levels ranged between 1.5 and 4.2 mg/l. All the values were within the acceptable limit (3mg/l) except one. There was a significant difference (P<0.05) between Station 1 and the other two stations. The nutrients occurred in low values and below acceptable limits. Nitrate values ranged from 0.9 to 3.4mg/l. Stations 1 and 3 were significantly different ($P< 0.05$). A range of 0.5 to 2.7 mg/l was recorded for phosphate and Station 3 was significantly lower than Stations 1 and 2.

3.2 Macroinvertebrate composition, abundance and distribution

The community structure of macroinvertebrates recorded in Ossah River, Umuahia are presented in Table 2. This study recorded a total of 119 macroinvertebrate individuals comprising of five taxonomic groups and twenty (20) taxa. Percentage composition of the taxa showed that non-biting midge, *Chironomus* sp had the highest abundance (39.5%), followed by mayfly nymph, *Cloeon* sp. (16%) and Back swimmer, *Notonecta* sp (7.6%) while the least were leech (*Hirudo medicinalis*), scud (*Gammarus pulex*), horsefly larvae (*Tabanus* sp.), water scorpion (*Ranatra linearis*) and water strider (*Gerris* sp.) contributing 0.8%. Spatially, the highest number of individuals was recorded in station 2 (57) while stations 3 and 1 had 37 and 25 individuals respectively.

Assessment of pollution tolerance status showed that most of the macroinvertebrates recorded are the tolerant and very tolerant species (75%) while the sensitive and very sensitive species were 25%. Most of the pollution indicators were recorded in Stations 1 and 2 which witnessed most anthropogenic impacts including effluent discharge. However, non-biting midge (*Chironomus* sp.) recorded their highest number in Stations 2 and 3.

The diversity indices showed that a higher Shannon-Wiener index (H) was recorded in station 1 (1.923) compared to 1.717 and 1.798 recorded in stations 2 and 3 respectively (Table 3). Station 2 had the highest Magalef Species Richness (2.968) while stations 1 and 3 recorded 2.796 and 2.769 respectively. Evenness Index ranged between 0.4285 and 0.6843; with the lowest and highest values recorded in stations 2 and 1 respectively.

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Table 1: Summary of Physico-chemical Parameters of Ossah River (with range in parenthesis)

Parameter	Station 1 x±SEM	Station 2 x±SEM	Station 3 x±SEM	P-value	FMENV. 2011
Water Temperature, ^{o}C	24.6±0.97 (21.0-28.0)	25.3±0.44 (24.0-27.0)	25.1±0.46 (24.0-26.5)	P>0.05	-
pH	5.4±0.22 (4.6-6.0)	5.6±0.21 (4.8-6.3)	5.6±0.19 (4.8-6.2)	P>0.05	6.5-8.5
Electrical Conductivity, µS/cm	98.5±4.52[a] (80.7-110.5)	73.8±4.34[b] (56.4-84.4)	58.4±2.34[c] (52.9-65.9)	P<0.05	-
Total Dissolved Solids, mg/l	49.4±2.06[a] (41.5-55.3)	36.8±2.33[b] (26.8-42.1)	29.1±71.24[c] (25.7-33.1)	P<0.05	-
Dissolved Oxygen, mg/l	5.1±0.29 (3.8-5.7)	5.7±0.26 (4.7-6.4)	4.8±0.35 (3.2-5.5)	P>0.05	>6
Biochemical Oxygen Demand, mg/l	3.3±0.33[a] (2.1-4.2)	2.1±0.20[b] (1.6-3.0)	2.1±0.15[b] (1.5-2.5)	P<0.05	3
Nitrate, mg/l	2.6±0.27[a] (1.7-3.4)	2.0±0.21[ab] (1.1-2.6)	1.8±0.28[b] (0.9-2.5)	P<0.05	50
Phosphate, mg/l	2.0±0.25[a] (0.9-2.7)	1.8±0.20[a] (0.1-2.3)	0.7±0.08[b] (0.5-1.0)	P<0.05	3.5

a, b , c = Means with different superscripts across the rows are significantly different at p<0.05; SEM= Standard Error of Mean; FMEnv. National Environmental (Surface and Groundwater Quality Control) Regulations

Table 2: Species composition, abundance and distribution of macroinvertebrate fauna encountered in Ossah River, Umuahia, Southeast Nigeria

Group	Family	Taxa	Station 1	Station 2	Station 3	Percentage	Pollution Status
Annelida	Hirudinea	Leech (*Hirudo medicinalis*)	0	1	0	0.8	Very Tolerant
Arachinida	Hydracarindae	Water mite (*Hydrachna* sp.)	2	1	0	2.5	Sensitive
	Pisauridae	Fishing spider (*Dolomedes* sp.)	1	2	1	3.4	Very Tolerant
Mollusca	Pleuroceridae	Gilled snail (*Pleurocera* sp.)	0	0	2	1.7	Very Tolerant
	Physidae	Pouched snail (*Physis* sp.)	0	3	3	5	Very Tolerant
Crustacea	Gammaridae	Scud (*Gammarus pulex*)	1	0	0	0.8	Very Tolerant
Insecta Megaloptera	Sialidae	Alderfly larvae (*Sialis* sp.)	2	0	1	2.5	Sensitive
Diptera	Chironomidae	Non-biting Midge (*Chironomus* sp.)	1	30	16	39.5	Very Tolerant
	Tipulidae	Cranefly larvae (*Tipula* sp.)	1	2	0	2.5	Tolerant
	Tabanidae	Horsefly larvae (*Tabanus* sp.)	0	1	0	0.8	Tolerant
Coleoptera	Dytiscidae	Predacious diving beetle *Dytiscus marginalis*	3	0	1	3.4	Very Tolerant
Hemiptera	Nepidae	Water scorpion (*Nepa cinerea*)	0	1	1	1.7	Very Tolerant
		Water scorpion (*Ranatra linearis*)	0	0	1	0.8	Very Tolerant
	Gerridae	Water strider (*Gerris* sp.)	1	0	0	0.8	Tolerant
	Notonectidae	Back swimmer (*Notonecta* sp.)	0	9	0	7.6	Very Tolerant
	Corixidae	Water boatman (*Corixa* sp.)	0	2	2	3.4	Very Tolerant
Ephemeroptera	Baetidae	Mayfly nymph (*Cloeon* sp.)	10	1	8	16	Very Sensitive
Coleoptera	Elmidae	Riffle beetle (*Elmis* sp.)	0	3	0	2.5	Sensitive
	Gyrinidae	Whirligig beetle (*Gyrinus* sp.	0	1	1	1.7	Tolerant
Odonata	Libellulidae	Dragonfly Larvae *Micromia* sp	3	0	0	2.5	Sensitive
	Total		**25**	**57**	**37**		

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Table 3: Diversity, species richness and evenness indices of macroinvertebrate fauna recorded in Ossah River, Umuahia, Southeast Nigeria.

Indices	Station 1	Station 2	Station 3
Number of Taxa (S)	10	13	11
Number of Individuals	25	57	37
Shannon (H)	1.923	1.717	1.798
Evenness (E)	0.6843	0.4285	0.5491
Margalef (D)	2.796	2.968	2.769

4. DISCUSSION

The recorded water temperatures were all within acceptable limits. Naturally, temperatures in water bodies vary daily and seasonally due to natural and anthropogenic activities that could affect surface water temperatures (Gebreyohannes *et al*., 2015). Water temperature is an essential water quality parameter; it directly affects physiological activities of aquatic organisms. The oxygen need of aquatic animals tend to increase abnormally with every 10°C increase within the animal's tolerable temperature range (Halim *et al*., 2018).

The pH is very important in water quality assessment because it influences other chemical reactions (Fakayode, 2005). pH values recorded were outside standard limits and could be attributed to geogenic influence (Anyanwu and Ihediwah, 2015) and anthropogenic activities (Amah-Jerry *et al*., 2017). Changes in pH can result from impacts of industrial pollutants; photosynthesis, respiration and decomposition also contribute to pH fluctuations due to their influences on CO_2 levels (Bellingham, 2012) while Radojevic and Bashkin (1999) observed that pollution result in extremes of pH in water. Consequently, changing the pH levels in every ecosystem affects all living organisms positively or negatively.

Total dissolved solids values were all within acceptable limit though higher TDS levels were recorded in Stations 1 and 2, indicating intense cumulative anthropogenic impacts in and around the stations. Clark (1994) observed that the most environmentally damaging impacts and associated social consequences sometimes may not be a product of a particular activity but as a result of complex interaction of many activities over time in the environment.

The electrical conductivity values were within acceptable limit and exhibited the same trend as TDS. Stations 1 and 2 were higher compared to station 3 and could be as a result of cumulative impact. Muhammad *et al*. (2013) reported that pure water is a poor conductor of electricity and the electrical conductivity of water increases with increase in ionic concentrations resulting from pollution. Pond *et al.* (2008) reported that increased dissolved ions could be responsible for poor benthic macroinvertebrate communities' structure and declining mayfly populations in streams receiving mining discharges.

All the recorded Dissolved Oxygen values were lower than acceptable limits except one. Murphy (2007) observed that animal and plant wastes as well as sewage are some of the ways by which organic materials can be discharged into natural water and the decomposition process of these organic materials by microbes require oxygen (Mahre *et al*., 2007). The functioning and survival of most biological communities can be negatively affected when DO levels fall below 5mg/l while death of most fish could occur at DO levels lower than 2mg/l (Chapman, 1996).

Biochemical Oxygen Demand (BOD) is an important parameter of water used in determining the pollution load of freshwater bodies (Bhatti and Latif, 2011). The mean BOD value of Station 1 exceeded limit while Stations 2 and 3 were within the acceptable limit. The BOD values recorded in Station 1 were relatively higher and could be as a result of cumulative impact (Clark, 1994).BOD is an indication of organic pollutant in the river and therefore affects water quality (Nwankwo *et al*., 2014).Chapman (1996) observed that unpolluted waters usually have BOD values of 2 mg/l or less while values up to 10 mg/l or more are usually associated with rivers receiving effluents, especially close to discharge point. On the other hand, Radojevic and Bashkin (1999) reported that self-purification in rivers is more effective at BOD value of less than 4, but less effective at values greater than 4 mg/l.

Nitrate levels in water are often less than 1 mg/l; surface waters can have values up to 5 mg/l when influenced by human activities and values in excess of 5 mg/l are usually indicative of pollution from anthropogenic sources (Chapman, 1996). The recorded values were within acceptable limit

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though Station 1 was significantly different from Station 3; which could be attributed to cumulative impacts.

Mandal *et al* (2012) observed that phosphate contamination comes from anthropogenic activities such discharge of detergent contaminated sewage, direct washing of clothes in water and runoffs laden with fertilizers and pesticides. Phosphate values recorded were within acceptable limit though Stations 1 and 2 were significantly different from Station 3. This could be attributed to cumulative impacts and effluent discharge. Phosphate values in most natural surface waters usually range between 0.005 and 0.020 mg/l (Chapman, 1996). Nutrients such as nitrogen and phosphates compounds have been implicated in the eutrophication of water bodies because they stimulate growth of algae and other photosynthetic aquatic life (Dubey *et al*., 2012).

The analysis of physicochemical parameters is an important method of getting reliable on-the-spot data on water quality and an insight into the nature of the contamination. Combination with additional biological evaluation is needed (Goldschmidt, 2016). On the other hand, since aquatic organisms spend most part of their life under certain conditions of the environment, biomonitoring provides for the quick integration of all impacts and enables a collective analysis of contributing factors as well as their complex interactions with reliability and cost-effectiveness (Valdecasas and Baltanás, 1990).

No new organism was recorded in this study (Olomukoro and Ezemonye, 2000; Olomukoro and Dirisu, 2012; Anyanwu and Jerry, 2017). The number of individuals was lower while the number of taxonomic groups and taxa was higher when compared 168 individuals, 4 taxonomic group and 7 taxa recorded in a suburban River in Umuahia (Anyanwu and Jerry, 2017). The species composition was dominated by group insecta as opposed to the group mollusca recorded by Anyanwu and Jerry (2017). Station 2 had the highest species richness while station 1 had the lowest and this could be as a result of the effluent discharged upstream of station 2. United Nations (2014) reported that although pollution occurs at discharge points along the river, its impacts are usually felt by downstream populations and ecosystems, because pollutants are distributed throughout the river network. The extent of impacts depends on the self-purification capability of the river through natural processes of dilution by runoff and degradation by micro-organisms (Wen *et al*., 2017).

Most of the species recorded were dominated by pollution tolerant groups especially *Chironomus* larvae. *Chironomus* spp are species indicators of organically polluted waters and can survive even in low oxygen waters (Mariantika and Retnaningdyah, 2014). The high number of *Chironomus* spp. recorded in station 2 is an indication of imbalance in the ecosystem resulting from instability in the water. Only certain types of organism like *Chironomus* sp. can thrive in such unstable environment because of their ability to cope with level of organic pollution (Mariantika and Retnaningdyah, 2014) and develop large populations (Kucuk, 2008).This finding was not in line with Anyanwu and Jerry (2017) that recorded the high species richness in station 3 instead station 2 that was most impacted; attributed to substrate stability. Station 3 recorded the lowest species richness but dominated by *Chironomus* larvae which could be attributed to macroinvertebrate drifting from station 2. Naman *et al* (2016) reported that the passive or active downstream movement of aquatic invertebrates known as invertebrate drift is a basic process in streams ecology.

Station 1 had highest evenness value as in case of Anyanwu and Jerry (2017) while station 2 was the least because one of the species (*Chironomus sp*) recorded was dominated by many individuals. The Shannon diversity indices were of higher value than that of Anyanwu and Jerry (2017). Station 1 had the highest value while station 2 had the lowest as in the case of Anyanwu and Jerry (2017). This may be as a result of the effluent discharged in close proximity of the station 2. Kucuk (2008) reported that when effluents are discharged into waters, community structure and density change. The low diversity recorded as reflected in Margalef, Shannon-Wiener and Evenness indices may be attributable to lower number of species and environmental degradation due to anthropogenic impacts, apart from other biotic factors (Ravera, 2001).

5. CONCLUSION

Some physicochemical parameters (pH, DO and BOD) and macroinvertebrate fauna of Ossah River showed that the river was adversely

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impacted by effluent from a vegetable oil processing factory in the vicinity and other anthropogenic activities in the watershed. The physicochemical parameters showed that station 1 was polluted by cumulative impacts from other anthropogenic activities while macroinvertebrate assemblages showed that station 2 was polluted by effluent discharge.

Acknowledgements

Conflict of Interest

There is no conflict of interest and writing assistant was not used in the preparation of this manuscript.

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